Inclusion of Dynamic Surface Information Improves GPM Precipitation Retrievals

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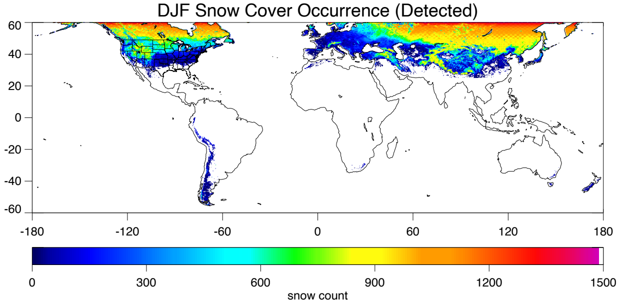
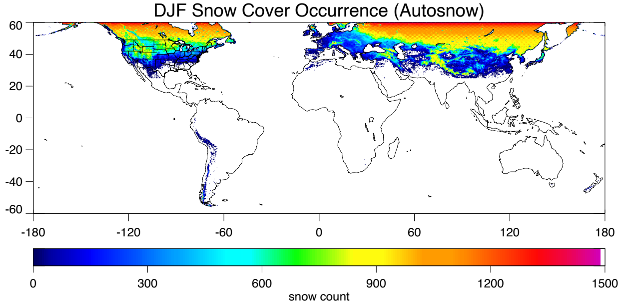
Using Surface Signal to Detect Snow Cover Compares to NOAA Global Snow Cover Product

DJF Snow Cover Occurrence (Detected)

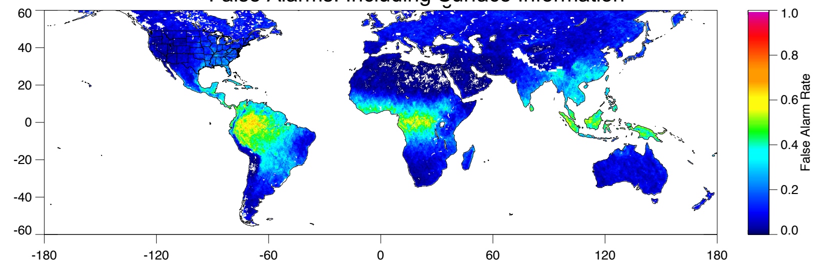


DJF Snow Cover Occurrence (Autosnow)

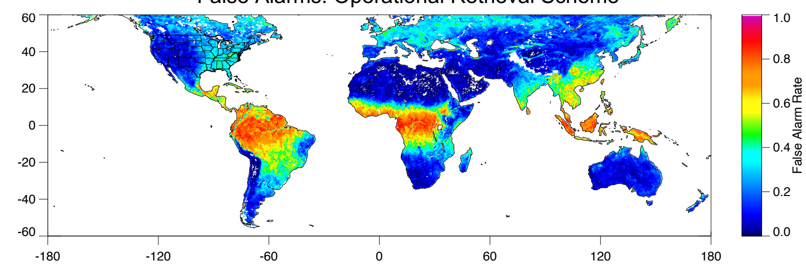


Including Surface Signal into Precipitation and Water Vapor Retrievals Decreases False Alarms

False Alarms: Including Surface Information



False Alarms: Operational Retrieval Scheme



The operational passive microwave precipitation retrieval for the Global Precipitation Measurement Mission (GPM) requires model constraints over land surfaces where the surface signal is strong, making light precipitation estimation difficult. Incorporating the surface signal via an optimal estimation retrieval allows for snow cover detection (left) and decreases the false alarm rate (right). Model data dependence is reduced and retrieval validation metrics improved, including decreasing probability of false detection by 50%.

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References:

S. Ringerud, C. Peters-Lidard, S. J. Munchak, Y. You, (2020), “Applications of Dynamic Land Surface Information for Passive Microwave Precipitation Retrieval”, *J. Atmos. And Ocean. Tech*., DOI: 10.1175/JTECH-D-20-0048.1

Data Sources: NASA Global Precipitation Measurement Mission (GPM) core satellite data from both the GPM Microwave Radiometer (GMI) and Dual Polarization Radar (DPR) are used in this analysis. The algorithms also include use of the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2).

Technical Description of Figures:

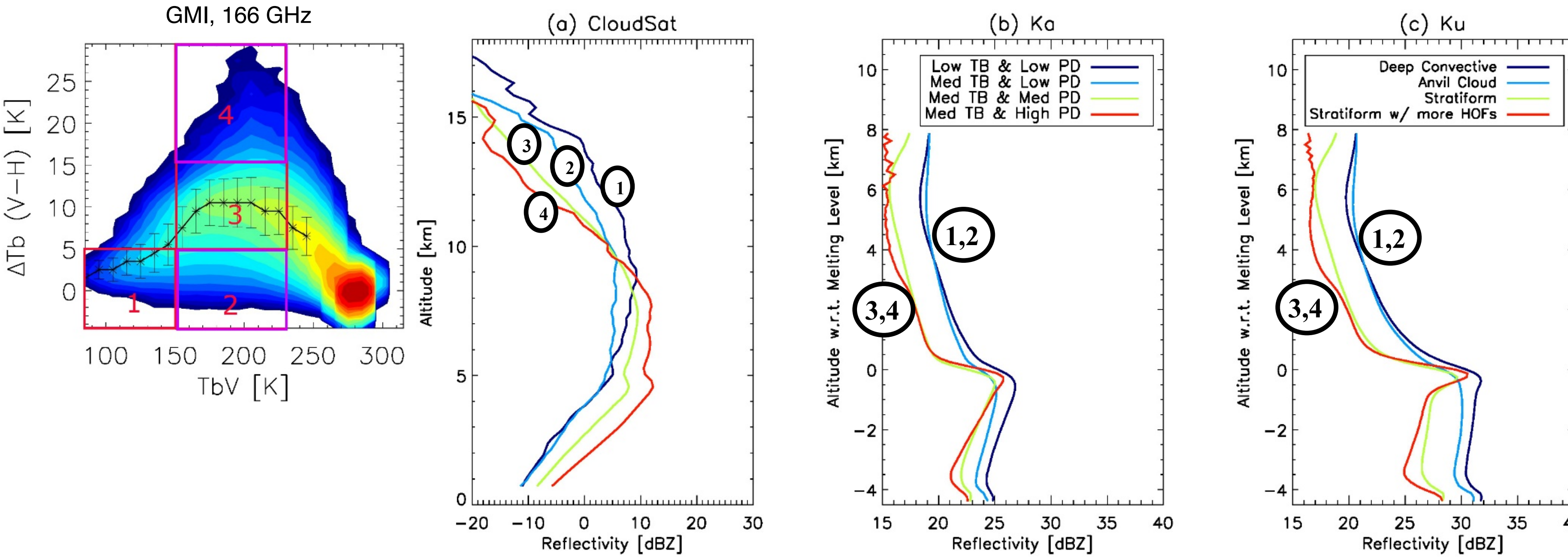
Graphic 1: (Left) Snow cover detection occurrence for GMI overpasses from the detection scheme using dynamic surface emissivity from the GMI Tbs (top panel) and the NOAA Autosnow product (bottom panels) over the seasonal period December-January-February (DJF) 2015-2016, demonstrating that results from the detection method are similar to the operational NOAA product.

Graphic 2: (Right) Ratio of retrieval false alarms (not detected by the active radar) to all observations for the one-year period September 2015-August 2016. The bottom panel shows results using the GPROF classification scheme, while the upper panel shows results using the hybrid retrieval incorporating dynamic surface emissivity information, demonstrating the global decrease in false alarms over land using the emissivity information.

Scientific significance, societal relevance, and relationships to future missions: Improving estimates of global precipitation is of fundamental importance for countless applications, ranging from real-time hazard monitoring to numerical weather prediction and global energy budgets. This was once again highlighted in the 2017 Decadal Survey and there is much to be learned from the NASA/JAXA Global Precipitation Measurement Mission (GPM) for designing the next generation that will begin looking into precipitation processes. Accurate, physically-based precipitation retrieval over global land surfaces is an important goal and a difficult problem for the passive microwave constellation, as the signal over radiometrically warm land surfaces in the microwave frequencies means that the measurements used are indirect, and typically require inferring some type of relationship between an observed scattering signal and precipitation at the surface. GPM, with collocated radiometer and dual-frequency radar, is an excellent tool for tackling this problem and improving global retrievals. In the years following the launch of the GPM core satellite, physically-based passive microwave retrieval of precipitation over land continues to be challenging. Validation efforts suggest that the operational GPM passive microwave algorithm, the Goddard Profiling Algorithm (GPROF) tends to overestimate precipitation at the low (< 5 mm/h) end of the distribution over land. In this work, retrieval sensitivities to dynamic surface conditions are explored through enhancement of the algorithm with dynamic, retrieved information from a GPM-derived optimal estimation scheme. The retrieved parameters describing surface and background characteristics replace current static or ancillary GPROF information including emissivity, water vapor, and snow cover. Results show that adding this information decreases probability of false detection by 50% and, most importantly, the enhancements with retrieved parameters move the retrieval away from dependence on outside ancillary datasets (such as snow cover) and lead to improved physical consistency. In addition to supporting the goals of GPM, this work is also relevant to the Aerosols, Clouds, Convection, and Precipitation 2017 Decadal Survey Designated Observables.

Satellite Observations reveal that Mesoscale Dynamics and Precipitation Life Stage have strong links to Ice Crystal Microphysics

Jie Gong (613, USRA) and Dong L. Wu (613, GSFC)



Using collocated measurements from CloudSat's radar (CPR), GPM's dual-frequency radar (DPR) and microwave imager (GMI), we find that large GMI 166 GHz Polarization Difference (PD) signals are promising indicators of horizontally aligned snow aggregates (HOFs) which are positively correlated with stratiform precipitation.

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References:

Gong, J., Zeng, X., **Wu, D. L.**, **Munchak, S. J.**, **Li, X**., Kneifel, S., Ori, D., **Liao, L., and Barahona, D.** (2020)**:** Linkage among ice crystal microphysics, mesoscale dynamics, and cloud and precipitation structures revealed by collocated microwave radiometer and multifrequency radar observations, *Atmosphere Chemistry and Physics*, 20, 12633–12653, doi: 10.5194/acp-20-12633-2020.

Data Sources: GPM data and collocated GPM CPR data are available to the public at https://pmm.nasa.gov/data-access/downloads/gpm. CloudSat and ECMWF-AUX data are made available from the CloudSat project at http://www.cloudsat.cira.colostate.edu/order-data. This work is mainly conducted under the support of NASA (grant nos. 80NSSC20K0087, NNX16AM06G, NNH18ZDA001N-RRNES). Dr. J. Turk (JPL) and Dr. C. Liu (TAMU Corpus Christi) are acknowledged for creating the collocated CloudSat-GPM dataset and squall line ensembles, respectively.

Technical Description of Figures:

Graphic: *left panel: 2-dimensional joint probability density function (2D-PDF) constructed from GMI 166 GHz TBv and PD observations over tropical ocean* ($30°S - 30°N$) *during July 2014 and 2015. TBv (TB_H) is the vertically (horizontally) polarized 166 GHz measured brightness temperature, and PD (or* ΔTB) *is defined as the difference between TBv and TB_H. Four cloud-precipitation regimes are defined within the rectangle boxes, corresponding to the four colored lines in the right panels: (1) TBv < 150 K, PD < 5 K (dark blue); (2) 150 K < TBv < 230 K, PD < 5 K (light blue); (3) 150 K < TBv < 230 K, 5 K < PD < 10 K (light green); (4) 150 K < TBv < 230K, PD > 15 K (red).*

Right three panels: averaged (a) CloudSat, (b) GPM-Ka and (c) GPM-Ku radar reflectivity profiles for the four regimes defined in the left panel. The 1st regime corresponds to deep convective scenes (dark blue); the latter three regimes cannot be differentiated using TB only, but correspond to anvil cloud (light blue), stratiform (green) and stratiform with significant amount (or big) snow aggregates (red), respectively, if TB and PD are used jointly. These mean profiles are integrated from all collocated tropical ($30°S - 30°N$) *pixels and weighted by their distribution at each level. (b) and (c) are composited based on the melting level height.*

Scientific significance, societal relevance, and relationships to future missions: NASA's 2017 Earth Science Decadal Survey prioritized cloud-convection-precipitation (CCP) as one of the 5 designated observables for future mission planning. This work provides a novel way of using polarized passive microwave measurements to study interlinked CCP processes. Leveraging on collocated spaceborne GPM-GMI, GPM-Ku, GPM-Ka and CloudSat W-band radars together with auxiliary temperature and wind information, we found that the differences between GMI 166 GHz polarized radiances are linked to ice microphysics (shape, size, orientation and density), mesoscale dynamic and thermodynamic structures, as well as surface precipitation stage (developing, mature or decaying). We conclude that passive sensors with multiple polarized channel pairs at microwave, sub-millimeter, infrared and visible wavelengths may be less expensive and greater spatiotemporal coverage substitutes for spaceborne multi-frequency radars for probing CCP processes. This work calls for more comprehensive understanding and modeling of radiative transfer involving non-spherical frozen hydrometers with preferential alignment especially at microwave and sub-millimeter spectrum, as well as more in-situ observations to resolve the ambiguity caused by large footprints and sparse/imperfect collocations between CloudSat and GPM.

The jet stream controls the summer surface O_3-temperature relationship

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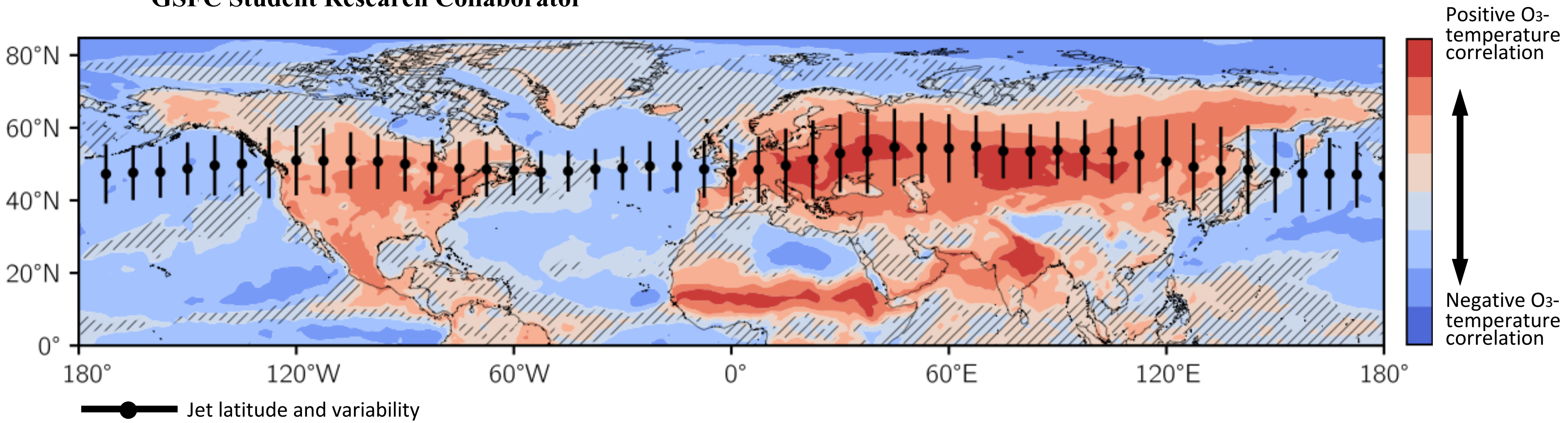
Sarah Strode, Steven Steenrod, Luke Oman, and Susan Strahan (Code 614), NASA/GSFC

* GSFC Student Research Collaborator



Understanding the relationship of surface level ozone (O_3) with temperature is a prerequisite for understanding O_3 pollution events and how O_3 may change under future warming.

A GMI CTM study shows the O_3-temperature relationship on daily timescales varies substantially over the Northern Hemisphere. For example, O_3 increases with increasing temperature over continental midlatitudes but decreases over the oceans with increasing temperature.

This relationship outside the tropics is related to the north-south movement of the jet stream and associated changes in the surface-level meridional flow, which impact the northward and southward advection of O_3 and temperature.

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References:
Kerr, G. H., Waugh, D. W., Strode, S. A., Steenrod, S. D., Oman, L. D., Strahan, S. E. (2019). Disentangling the drivers of the summertime ozone-temperature relationship over the United States. *Journal of Geophysical Research Atmospheres.* 124(19):10503-10524. https://doi.org/10.1029/2019JD030572.
Kerr, G. H., Waugh, D. W., Steenrod, S. D., Strode, S. A., and Strahan S. E. (2020). Surface ozone-meteorology relationships: Spatial variations and the role of the jet stream. *Journal of Geophysical Research Atmospheres.* 125(21):e2020JD032735. https://doi.org/10.1029/2020JD032735.

Data Sources:
The NASA Global Modeling Initiative (GMI) chemical transport model (CTM) was used to simulate surface-level O_3 for 2008-2010. Multiple sensitivity simulations of the GMI CTM isolated the roles of transport, chemistry, and anthropogenic emissions on the O_3-temperature relationship.
The NASA Global & Modeling Assimilation Office (GMAO) Modern Era Retrospective for Research and Applications, Version 2 (MERRA-2) renalysis was used to drive the GMI CTM as well as characterize the meteorology associated with variations in the O_3-temperature relationship.

Technical Description of Figures:
Graphic 1: The correlation coefficient calculated between surface-level O_3 from the GMI CTM and MERRA-2 2-meter temperature, r (T, O_3). Hatching denotes regions where the correlation is not statistically significant, determined using moving block bootstrap resampling to estimate the 95% confidence interval. Scatter points and vertical bars specify the mean position and variability of the jet stream, respectively.

Scientific significance, societal relevance, and relationships to future missions:
The NASA GMI CTM and *in-situ* observations indicate significant spatial variations in the sign and strength of the correlation of O_3 with temperature. In continental regions of the midlatitudes, O_3 and temperature are significantly positively correlated, while the correlation is negative over the ocean basins and weak at high latitudes and in the tropics. Sensitivity simulations of the GMI CTM indicate that daily variations in the O_3-temperature relationship are largely driven by transport-related phenomena.

The variability of O_3 and temperature are linked to the meridional movement of the jet stream in the Northern Hemisphere midlatitudes. Over land in the midlatitudes, a poleward (equatorward) shift of the jet is associated with increased (decreased) surface-level O_3 and temperature. Over the oceans, temperature responds to this meridional movement of the jet in the same fashion as over land, but the poleward (equatorward) movement of the jet decreases (increases) O_3. The jet influences the O_3-temperature relationship through its effects on the surface-level meridional flow, which acts on the background latitudinal gradients of O_3 and temperature, and not due to cyclones and the associated frontal activity, as has been previously suggested.

This research is directly responsive to Science and Application Objective W-7 put forth in the 2017 Decadal Survey to understand processes that control tropospheric O_3 variations and trends as well as their impact on atmospheric composition. Our results underscore the importance of considering the role of the jet stream and surface-level flow for understanding the O_3-temperature relationship, especially in light of expected changes to these features under climate change.